Litter production by mangroves. I: Mgeni Estuary

T.D. Steinke and L.M. Charles
Department of Botany, University of Durban-Westville, Durban

Litter fall was measured in two mangrove communities: one dominated by *Avicennia marina* (Forsk.) Vierh. and the other comprising an almost pure stand of *Bruguiera gymnorrhiza* (L.) Lam. Mean litter production for the *A. marina* community was 1,91 g dry matter $m^{-2}day^{-1}$ or 6,98 tons $ha^{-1}year^{-1}$ over a 3-year period, while the values for the *B. gymnorrhiza* stand were 2,26 g dry matter $m^{-2}day^{-1}$ or 8,24 tons $ha^{-1}year^{-1}$ over 4 years. Highest litter values in both communities were obtained when seedlings were shed in autumn. The *A. marina* community produced extremely variable yields of litter components and total litter from year to year, whereas the yields from *B. gymnorrhiza* were more consistent. Mean annual leaf yield comprised 59,0% and 62,5% of the total litter in the *A. marina* and *B. gymnorrhiza* communities respectively. In the *B. gymnorrhiza* stand stem material constituted only 6,0% of the total litter yields, while in the *A. marina* community the contribution was 17,8%. From the 44 ha occupied by mangroves it is calculated that total litter production is 334,2 tons $year^{-1}$, of which approximately 200 tons $year^{-1}$ is leaf litter. This is considered to provide a significant input to this system.

S. Afr. J. Bot. 1986, 52: 552 – 558

Die afvalopbrengs is vir twee manglietgemeenskappe bepaal: die een gemeenskap word deur *Avicennia marina* (Forsk.) Vierh. oorheers terwyl die ander een byna uitsluitlik uit *Bruguiera gymnorrhiza* (L.) Lam. bestaan. Die gemiddelde afvalopbrengs vir die *A. marina*-gemeenskap was 1,91 g droë materiaal $m^{-2}dag^{-1}$ of 6,98 ton $ha^{-1}jaar^{-1}$ oor 'n tydperk van 3 jaar terwyl die waardes vir die *B. gymnorrhiza*-gemeenskap 2,26 g droë materiaal $m^{-2}dag^{-1}$ of 8,24 ton $ha^{-1}jaar^{-1}$ oor 'n periode van 4 jaar was. Die hoogste afvalopbrengs, in beide gemeenskappe, is gedurende die herfs verkry toe die saailinge versprei is. Die opbrengs van die *A. marina*-gemeenskap ten opsigte van totale afval en afvalbestanddele was uiters wisselvallig van jaar tot jaar terwyl die opbrengs van die *B. gymnorrhiza*-gemeenskap meer bestandig was. Gemiddelde jaarlikse blaaropbrengs van die *A. marina*- en *B. gymnorrhiza*-gemeenskappe het onderskeidelik 59,0% en 62,5% van die totale afval uitgemaak. In die *B. gymnorrhiza*-gemeenskap het die stingelkomponent van die afval slegs 6,0% van die totaal bedra terwyl die *A. marina*-gemeenskap se bydrae 17,8% was. Dit is bereken dat die totale afvalopbrengs van die 44 ha wat deur mangliete beslaan word 334,2 ton $jaar^{-1}$ is waarvan ongeveer 200 ton $jaar^{-1}$ blaarafval is. Dit word as 'n betekenisvolle toevoeging van plantvoedingstof tot hierdie stelsel beskou.

S.-Afr. Tydskr. Plantk. 1986, 52: 552 – 558

Keywords: Estuary, litter, mangrove

T.D. Steinke* and L.M. Charles
Department of Botany, University of Durban-Westville, Private Bag X54001, Durban, 4000 Republic of South Africa

*To whom correspondence should be addressed

Accepted 9 June 1986

Introduction

Mangroves are constituents of many of the estuaries in Transkei and Natal (Ward & Steinke 1982). As there is evidence for the importance of mangrove detritus as the basis for estuarine production (Odum & Heald 1972), it was considered necessary to quantify litter fall as part of an attempt to obtain an understanding of the role of mangrove communities in southern African estuarine ecosystems. For this reason a study was initiated at Mgeni estuary where litter production by the two common mangrove species in that system, viz. *Avicennia marina* (Forssk.) Vierh. and *Bruguiera gymnorrhiza* (L.) Lam. was determined. Additionally, as field observations in the mangroves had indicated that production might show variation between years, it was decided to monitor litter fall over a period of years and to partition the litter among its components.

Study Area

The project was conducted in the Beachwood mangrove swamp at the mouth of the Mgeni River. The Beachwood area, which is long and narrow (approximately 2,60 km × 0,35 km), lies roughly in a NE – SW direction, parallel to the coast. The mangroves occur along the stream separating a range of dunes on the seafront from scrub and urban development on the landward side. The main mangrove species are *Bruguiera gymnorrhiza* and *Avicennia marina*, although *Rhizophora mucronata* Lam. is also present. The total area of mangroves in the Mgeni estuary was calculated from aerial photographs to be 44 ha (Ward & Steinke 1982), of which 11,6 ha, 10,6 ha and 21,8 ha represent areas largely of *A. marina, B. gymnorrhiza* and a mixed *A. marina – B. gymnorrhiza* community respectively. The mangrove communities of the Beachwood area have been described by Padia (1980).

Two areas near the mouth were chosen for this study: a community dominated by *A. marina* and an almost pure stand of *B. gymnorrhiza*. The *A. marina* community (1,25 ha in extent) comprised scattered tall trees (9 m) with increasing numbers of *B. gymnorrhiza* (7 m) towards the west and north where the latter form a dense fringe. An occasional tree or sapling of *R. mucronata* is also present. The *B. gymnorrhiza* community (0,67 ha), in which only occasional mature trees of *A. marina* were present, showed a decrease in height from 7 m near the water's edge to 3 m at the landward margin. The *A. marina* community is inundated at most high tides, while tidal coverage in the *B. gymnorrhiza* community occurs only at spring tides.

Materials and Methods

To ensure that samples were representative of each population, sampling was carried out using a stratified random technique (Rayner 1969). In the *A. marina* and *B. gymnorrhiza* stands 15 and 10 litter baskets respectively, each measuring 0,25 m^2 in area, were utilized. The area in each stand was divided into strata and a basket positioned by choice of random numbers within each stratum. The project commenced in October 1978, and was continued for 3 and 4 years in the *A. marina* and *B. gymnorrhiza* stands respectively. Each year of the study runs from October to September. Collections of litter were made fortnightly except in the fourth year of the study when the *B. gymnorrhiza* baskets were emptied at 4-weekly intervals. The harvested material from the baskets in the *A. marina* stand was separated into leaves, stems, reproductive material and *B. gymnorrhiza* components. It was not possible to

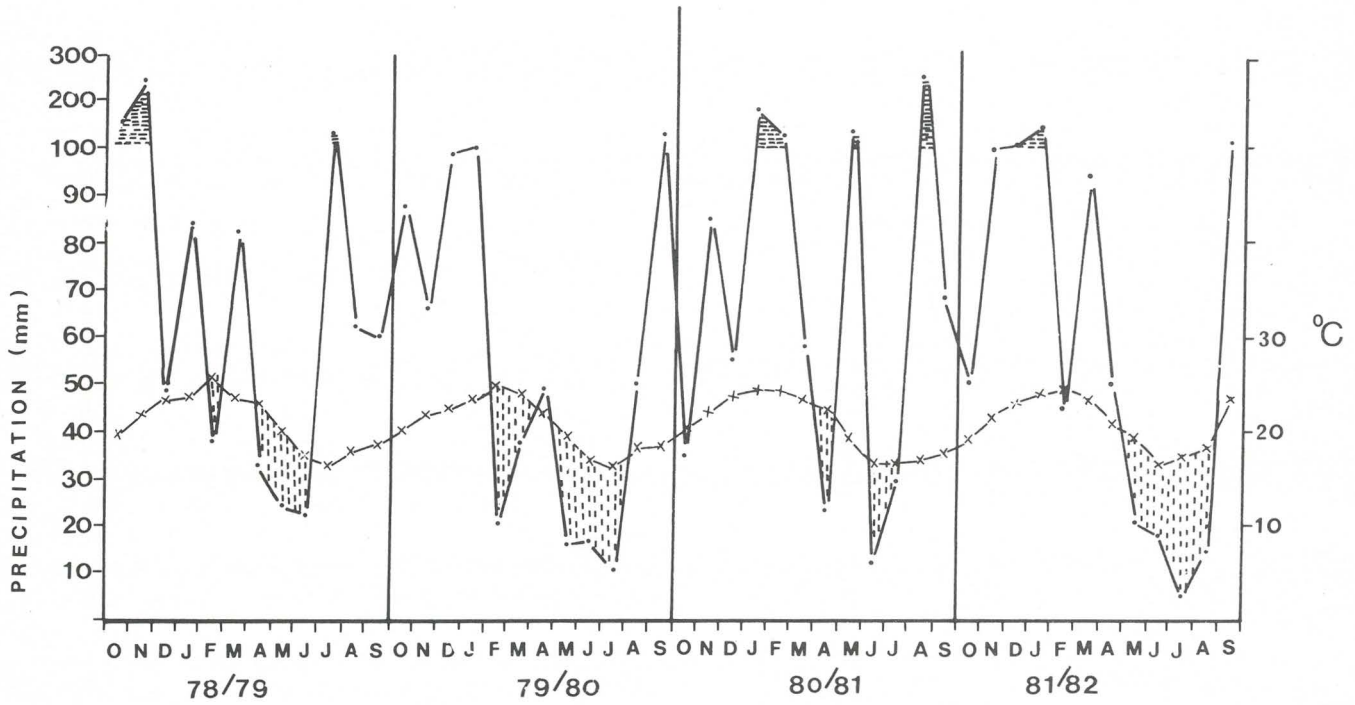

Figure 1 Climate diagrams for the period 1978/79 to 1981/82 for the Durban area (Weather Station Louis Botha Airport).

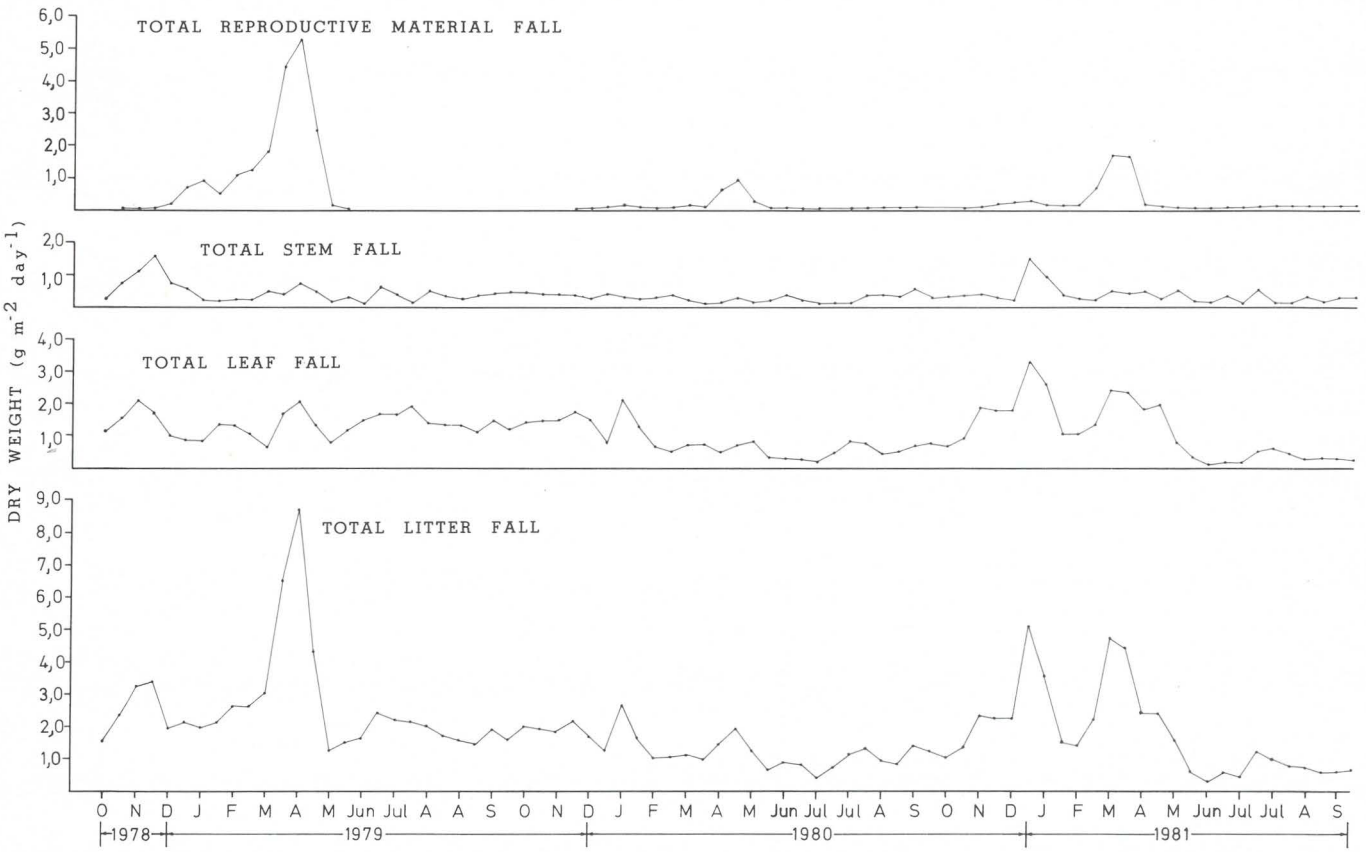

Figure 2 Mean daily litter production in the *A. marina* community for the period 1978/79 to 1980/81.

separate *A. marina* buds, flowers and propagules, which were therefore considered together as reproductive material. The material from the baskets in the *B. gymnorrhiza* stand was separated into leaves, stems, propagules, miscellaneous (which comprised stipules, flowers and calyces) and *A. marina* components. The separated material was oven-dried at 70°C for a week and then weighed.

Climate diagrams are given for the period of the project (Figure 1). Climatic data were supplied by the Weather Office, Louis Botha Airport, Durban.

Results

A. marina community

The trends in mean daily mass of litter fall are presented in Figure 2, while the contribution by individual litter components to total litter are shown in Table 1 and Figure 3. In Figures 2 & 4 some months, e.g. June 1982, occur twice on the X-axis because the intervals on that axis are 4-weekly.

Table 1 Mean dry matter yields of litter components (g $m^{-2}d^{-1}$) in the *Avicennia marina* community

	A. marina				
Harvest years	Leaves	Stems	Reprod. mat.	*B. gymnorrhiza*	Total
1978/79	1,34	0,44	0,71	0,12	2,61
	Aa	Aa	Aa	N.S.	Aa
1979/80	0,81	0,24	0,09	0,15	1,29
	Bb	Bb	Bb	N.S.	Bc
1980/81	1,16	0,33	0,24	0,11	1,84
	ABa	ABab	Bb	N.S.	Bb

Any two treatments which do not have a letter in common differ significantly: small letters denote significance at the 5% level, capital letters show significance at the 1% level

Where data do not appear in these figures, there were no values recorded for those sampling periods.

Mean daily mass of fall of total litter showed peaks in April 1979, in December 1980/January 1981, and again in March/April 1981. Several smaller peaks, i.e. October/November 1978, January 1980 and April/May 1980, introduced variation to an otherwise fairly regular pattern. The reason for these peaks may be found in the fall of reproductive material, very often coincident with a higher leaf fall, or in leaf or stem fall.

In general, high values for litter were obtained when seedlings were shed in the autumn. Reproductive material made a significant contribution to the litter yield in 1978/1979 (27,2%), but yields in subsequent years were low. While in 1979 no reproductive material was collected in the baskets between May and November, this component subsequently made small contributions to the litter yield throughout the year.

A. marina leaf fall during the 3 years of recordings averaged 1,34; 0,81 and 1,16 g $m^{-2}d^{-1}$ respectively, of which only the value for 1979/1980 was significantly lower. The mean contribution of leaves to the total litter output was 59,0%. In 1978/1979 the low relative percentage contribution (51,3%) was clearly due to the high yield of propagules. Higher leaf litter yields appeared to coincide with propagule fall, but more information is necessary before a definite relationship can be established. Although there were peaks in leaf fall, other than at the time of propagule fall there were no clear trends during the year.

One such peak for which an explanation is possible occurred in October/November 1978 when high leaf and stem values were caused by unseasonally strong winds which followed a period of very wet, warm weather (Figure 2). Similar conditions seemed to prevail in December 1980 when a peak in leaf and stem fall was obtained. However, stem material generally formed a small component of the litter

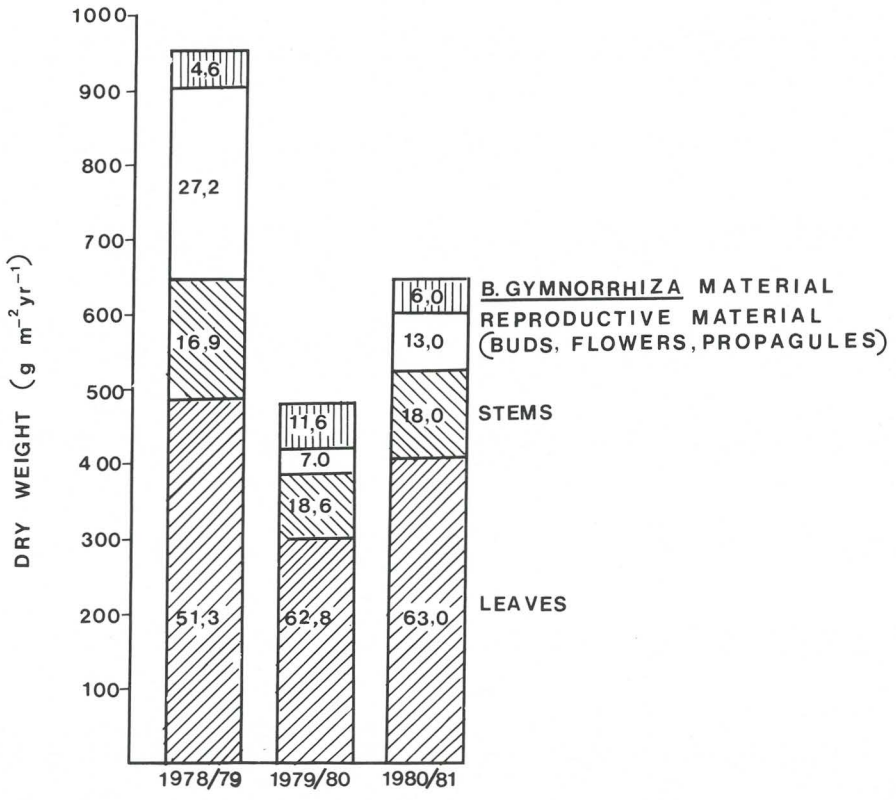

Figure 3 Composition of total litter fall for three consecutive years for the *A. marina* community. Individual components of litter production are given as percentage of total litter fall.

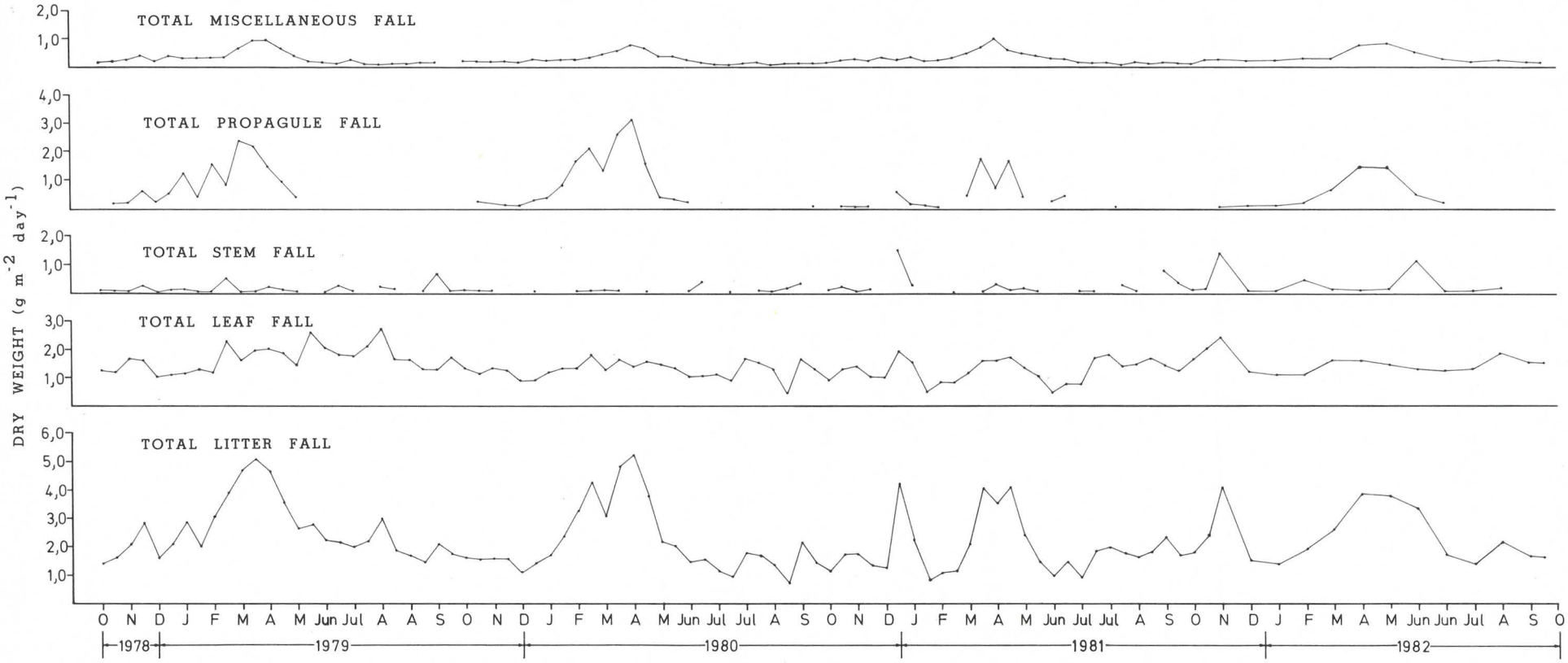

Figure 4 Mean daily litter production in the *B. gymnorrhiza* community for the period 1978/79 to 1981/82.

(mean value only 17,8%) and comprised largely broken twigs, small branches and flakes of corky material.

It can be seen from the results that total litter fall showed significant variation between years. In the 3 years of this project total litter dry masses were 952,18; 471,20 and 670,60 g $m^{-2}yr^{-1}$ respectively, giving a mean total value of 697,99 g $m^{-2}yr^{-1}$ or 6,98 t $ha^{-1}yr^{-1}$ (Table 3). The climate diagrams (Figure 1) indicate that in 1979/80, the year in which the least litter was produced, there was a prolonged dry period stretching from January to August. This was in contrast to most years when good rains were received at that time. Although it is possible that this factor was responsible for the low leaf and stem productivity during that year, the climate data do not appear to explain the variability in propagule production.

B. gymnorrhiza community

The trends in mean daily mass of litter fall are presented in Figure 4, while the contribution by individual litter components to total litter are shown in Table 2 and Figure 5.

Most of the peaks in total litter fall (Figure 4) were associated largely with the fall of propagules. Steinke & Charles (1984) have shown that at Beachwood the peak in propagule fall coincides with the contribution of flowers and aborted calyces to the litter baskets, and these minor peaks are reflected in the miscellaneous components of the litter. Propagule production averaged 18,4% of total litter, but the high value (26,9%) for 1979/80 was partly responsible for the relatively low contribution of leaves in that year. This high value was followed by a significantly lower yield in the next year.

Table 2 Mean dry matter yields of litter components (g $m^{-2}d^{-1}$) in the *Bruguiera gymnorrhiza* community

	B. gymnorrhiza					
Harvest years	Leaves	Stems	Propagules	Miscellaneous	*A. marina*	Total
1978/79	1,66 Aa	0,10 ABab	0,50 ABab	0,29 N.S.	0,04	2,59 Aa
1979/80	1,26 Bb	0,05 Bb	0,57 Aa	0,23 N.S.	0,01	2,12 ABbc
1980/81	1,26 Bb	0,16 ABab	0,25 Bc	0,28 N.S.	0,01	1,96 Bc
1981/82	1,47 ABa	0,22 Aa	0,34 ABbc	0,30 N.S.	0,02	2,35 ABab

Any two treatments which do not have a letter in common differ significantly: small letters denote significance at the 5% level, capital letters show significance at the 1% level

Mean annual *B. gymnorrhiza* leaf fall for the duration of this project were 1,66; 1,26; 1,26 and 1,47 g $m^{-2}d^{-1}$ respectively, of which the values for 1979/80 and 1980/81 were significantly lower. The mean contribution of leaves to the total litter output was 62,5%. Peaks in leaf fall were not associated with propagule fall, it rather appeared that high values for leaf litter were coincident with stem fall. Stem fall formed only a very small component (mean value 6,0%) of the litter and consisted largely of small, usually terminal, twigs. It was difficult to establish significant differences because the stem data were extremely variable. Stem fall was not regular or seasonal and, as indicated for the *A. marina* community, weather conditions were probably responsible for some of the peaks; from observation, high yields being obtained following strong winds.

The *A. marina* component was not analysed statistically as only four baskets made a contribution towards these yields.

Yields of total litter and individual components were not as variable as in the *A. marina* community (Tables 1 & 2). For the 4 years of the project total litter dry masses were 945,96; 774,71; 716,80 and 857,25 g $m^{-2}yr^{-1}$ respectively, giving a mean total value of 823,68 g $m^{-2}yr^{-1}$ or 8,24 t $ha^{-1}yr^{-1}$ (Table 3). No marked reductions in litter yields occurred in 1979/80 and consequently it is doubtful if the prolonged dry period was in fact the reason for the low litter yields in the *A. marina* community in that year.

Mixed *A. marina* – *B. gymnorrhiza* community

No litter baskets were placed in an area occupied by this community. However, field observations of the community indicate that a fair estimate of litter production would be obtained by averaging the yields for the above two communities.

Discussion

Mean litter production for this estuary was calculated as 7,61 t $ha^{-1}yr^{-1}$. This is lower than the overall mean of litter production in north-east tropical Australia (Bunt 1982) or in Florida (Pool *et al.* 1975), but compares well with the yields from Biscayne Bay, Florida (Teas 1976), and exceeds the values for temperate Australia (Goulter & Allaway 1979) and New Zealand (Woodroffe 1982).

It would appear that litter yields decline with increasing distance from the tropics. On present evidence this can only be a very generalized conclusion because from field observations it is clear that variations occur between communities even in the same geographic area.

Using the mean litter yields and the mean percentage

Table 3 Calculated mean total litter production of mangrove communities at Mgeni estuary

			Litter components t yr^{-1}					
			Leaves					
Community	Total area ha	Mean litter yield t $ha^{-1}yr^{-1}$	*A. marina*	*B. gymnorrhiza*	Stems	Reproductive material	Miscellaneous	Total litter t yr^{-1}
A. marina	11,6	6,98	47,8	4,4	14,4	12,7	1,7	81,0
B. gymnorrhiza	10,6	8,24	0,7	54,6	5,2	16,0	10,8	87,3
Mixed *A. marina* – *B. gymnorrhiza*	21,8	7,61	45,6	60,3	18,9	28,4	12,7	165,9
Total Mgeni estuary	44,0	–	94,1	119,3	38,5	57,1	25,2	334,2
			213,4					

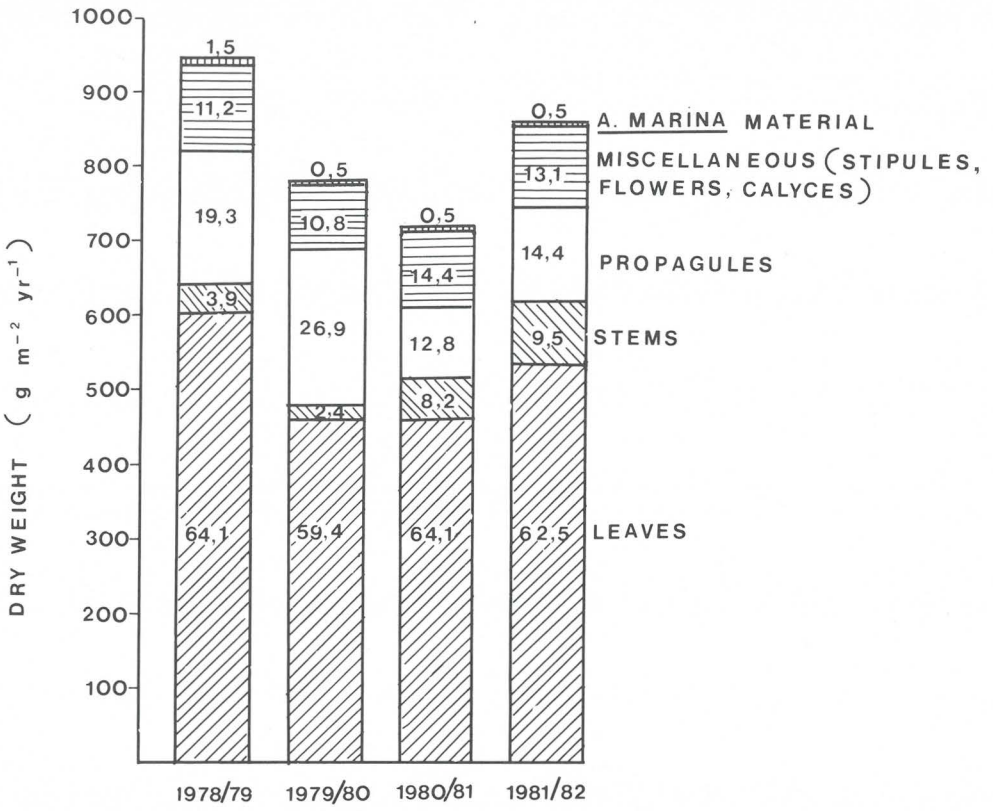

Figure 5 Composition of total litter fall for four consecutive years for the *B. gymnorrhiza* community. Individual components of litter production are given as percentage of total litter fall.

contributions by individual litter components, total litter production of the mangrove communities in the Mgeni estuary was estimated to be 334,2 t yr^{-1} (Table 3). Of this output 213,4 t yr^{-1} (or almost 64%) were made up of leaves, while reproductive and stem material comprised less than 17 and 12% respectively. It is possible that with baskets of greater area a slightly higher value for stems might have been obtained, although, of the work quoted above, only the tropical Australian study used larger baskets.

From the litter data it is possible to obtain estimates of net primary productivity (NPP) for these mangroves. It must be appreciated, however, that litter does not reflect the full extent of net photosynthetic yield, as other components of production (viz. major stems, roots) are neglected. Based on the formula proposed by Golley *et al.* (1962) and using the calculated litter production of 334,2 t yr^{-1} (Table 3), total NPP for these mangrove communities is estimated as 501,30 t C yr^{-1}. This value approximates more closely to yields from temperate rather than tropical forests (Bell *et al.* 1978) and it is suggested that this can be ascribed to the fact that these mangroves are approaching the southernmost limit of their distribution.

Previous work at Beachwood (Steinke *et al.* 1983) on the degradation of mangrove leaf and stem litter revealed that leaves degraded fairly rapidly with a concomitant release of nutrients, while the stems broke down very slowly. The contribution of leaf litter in excess of 200 t yr^{-1} probably provides a significant input to this system. This underlines the importance of mangroves and the contribution they make to the estuarine food web. In the light of these results the destruction of mangroves that has taken place fairly extensively in the recent past must be viewed with concern. To enable a more complete assessment of the importance of litter production by mangroves, litter studies are presently being conducted in estuaries to the north and south of the Mgeni estuary.

Acknowledgements

The writers wish to thank Prof A.L. Smit for the Afrikaans translation of the Abstract, Mr C.J. Ward for his helpful comments on the script and Mr R. Sookrajh and E.L. van Hooff for their assistance with the diagrams. To Messrs P. Singh and S. Kasavan thanks are due for the litter collections. Mrs R. Bunsee kindly typed the article. The co-operation of the Natal Parks, Game and Fish Preservation Board is also gratefully acknowledged.

References

BELL, D.T., JOHNSON, F.L. & FILMORE, A.R. 1978. Dynamics of litter fall, decomposition and incorporation in the streamside forest ecosystem. *Oikos* 30: 76 – 82.

BUNT, J.S. 1982. Studies of mangrove litter fall in tropical Australia. In: Mangrove Ecosystems in Australia. ed. Clough, B.F. ANU Press, Canberra.

GOLLEY, F.B., ODUM, H.T. & WILSON, R.F. 1962. The structure and metabolism of a Puerto Rican red mangrove forest in May. *Ecology* 43: 1 – 19.

GOULTER, P.F.E. & ALLAWAY, W.G. 1979. Litter fall and decomposition in a mangrove stand, *Avicennia marina* (Forsk.) Vierh. in Middle Harbour, Sydney. *Aust. J. mar. Freshwat. Res.* 30: 541 – 546.

ODUM, W.E. & HEALD, E.J. 1972. Trophic analyses of an estuarine mangrove community. *Bull. mar. Sci.* 22 671 – 738.

PADIA, R. 1980. A vegetation map of the Mgeni/Beachwood Nature Reserve, Durban, from aerial photographs. B.Sc. Hons. project, Univ. of Durban-Westville.

POOL, D.J., LUGO, A.E. & SNEDAKER, S.C. 1975. Litter production in mangrove forests of southern Florida and Puerto Rico. In: Proc. Internat. Symp. Biol. Mgmt Mangroves, Hawaii. eds. Walsh, G.E., Snedaker, S.C. & Teas, H.J. University of Florida, Gainesville.

RAYNER, A.A. 1969. A first course in biometry for agriculture students. University of Natal Press, Pietermaritzburg.

STEINKE, T.D. & CHARLES, L.M. 1984. Productivity and

phenology of *Avicennia marina* (Forsk.) Vierh. and *Bruguiera gymnorrhiza* (L.) Lam. in Mgeni estuary, South Africa. In: Physiology and management of mangroves, ed. Teas, H.J. W. Junk, The Hague.

STEINKE, T.D., NAIDOO, G. & CHARLES, L.M. 1983. Degradation of mangrove leaf and stem tissues *in situ* in Mgeni estuary, South Africa. In: Biology and ecology of mangroves, ed. Teas, H.J. W. Junk, The Hague.

TEAS, H.J. 1976. Productivity of Biscayne Bay mangroves. Univ. Miami Sea Grant Special Report No. 5: 103 – 112.

WARD, C.J. & STEINKE, T.D. 1982. A note on the distribution and approximate areas of mangroves in South Africa. *S. Afr. J. Bot.* 1: 51 – 53.

WOODROFFE, C.J. 1982. Litter production and decomposition in the New Zealand mangrove, *Avicennia marina* var. *resinifera*. *N.Z. J. mar. Freshwat. Res.* 16: 179 – 188.